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The analysis of PV power potential and system installation in Manavgat, Turkey—A case study in winter season

Selami Kesler [a], Sinan Kivrak [a], Furkan Dincer [b,*], Sabir Rustemli [c], Muharrem Karaaslan [d], Emin Unal [d], Utku Erdiven [e]

[a] *Pamukkale University, Department of Electrical and Electronics Engineering, 20020 Denizli, Turkey*
[b] *Mustafa Kemal University, Department of Computer Engineering, 31200 Hatay, Turkey*
[c] *Bitlis Eren University, Department of Electrical and Electronics Engineering, 13000 Bitlis, Turkey*
[d] *Mustafa Kemal University, Department of Electrical and Electronics Engineering, 31200 Hatay, Turkey*
[e] *Cukurova University, Department of Physics, 01330 Adana, Turkey*

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ABSTRACT

This study presents an analysis of solar energy potential and data with seasonal variation in region of Manavgat in Antalya, which has one of the highest solar energy potential in Europe. Expectation in the region is simulated for every month and measurements taken from PV power system installed there are compared with simulated results in winter season. Also, some actual harvested data from thin films and monocrystalline types are presented as a case study to evaluate the solar energy potential of the region, comparatively. Besides, importance of the sun tracking system is emphasized by simulation studies via PV Geographical Information System (PVGIS) from point of increasing the yields in selected region. Estimated results from two-axis tracking system are evaluated and compared with output of the fixed-angle PV systems installed there for both thin film and monocrystalline type PV panels. Also, temperature effects on performance of the PV systems are reviewed briefly because of daily high temperature of the region. In particular, it is observed that harvested solar energy from thin film type panels is close to the monocrystalline types, depending on the less effects of high ambient temperature on thin film PV panel′s efficiency with respect to the monocrystalline type. Specifically, despite the high solar energy potential, this PV power system installation is the first project in the region. Thanks to this project it is evaluated that thin-film PV panels can be used in the region more favorable, which can be obtained cheaper than the others.

Contents

1. Introduction

Nowadays, the world economic developments, the widespread use of technology and the growing population cause need for

* Corresponding author.
E-mail address: furkandincer@mku.edu.tr (F. Dincer).

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more energy. So, energy has become an essential element for economic growth and social progress. Therefore, the usage of energy is of great importance. At the same time, primary energy sources of the world are fossil fuels, unfortunately and also it is obviously known that these sources cause to affect global warming adversely [1]. In addition to that, one key argument for an accelerated deployment of renewable energies in general and PV in particular they have environmental benefits, besides the avoided risk of disruption in fossil fuel supply and the associated price instability [2]. Therefore, many researchers study on these subjects and try to find a reasonable solution for this problem. Li and Chen [3] report that International Energy Agency estimates the cities account for 67% of energy consumption worldwide, and along with this figure, which is expected to rise, brings into our view those cities will host 60% of world's population by 2030. Also, Alamdari et al. [4] note that the global energy consumption is estimated to climb around 32.922 TW in 2035. They also outline that renewable energies eliminate the problems associated with fossil and nuclear energies such as pollution and environmental damages. Boukelia and Mecibah [5] note that the global demand for energy and specifically more clean energy is growing rapidly.

To bring up importance of carbon-free energy generation and to produce it more, lots of scientist in the world has been working with heart and soul. Behar et al. [6] note that recent studies and technology roadmaps published by the International Energy Agency (IEA), the German Aerospace Center (DLR) and the European Union (EU) have projected that 80% of the CO_2 emissions, by 2035, will be from current industry-based economy; so that changes in the climate will intensify if no decisive actions are undertaken by these countries. Fazelpour et al. [7] report that the sun harnessing becomes a chief role player in search for clean energy as a gradually result of technology advances, serious environmental awareness, growing electricity demands and limited fossil resources. With understanding importance of carbon-free energy generation, solar electricity with photovoltaic technology has received heightened attention as a potentially widespread approach to sustainable energy generation. Thirugnanasambandam et al. [8] put forward that the use of solar energy in recent years has reached a remarkable edge. Tyagi et al. [9] classify that one of the most potential applications of solar energy is the supply of hot air for the drying of agricultural, textile, marine products, heating of buildings to maintain a comfortable environment. Also, it is exposed that solar energy has obviously environmentally advantageous relative to any other energy source and solar energy is the linchpin of any serious sustainable development program. Besides, the sun is the world's most abundant and permanent energy source which emits energy at a rate of 3.8×10^{23} kW, of which, approximately amount of 1.8×10^{14} kW is intercepted by the earth [10–16]. Also, Zhang et al. [17] note that more energy from the sunlight strikes the earth in 1 h than all of the energy consumed by humans in an entire year.

On the other hand, there are many studies on environmental characteristic of solar energy. Zhang and He [18] express that solar energy resources are abundant, widely available and one of the major renewable energy sources which have the greatest development potential. And they note that power generation from PV is clean, safe, convenient, and highly efficient. Also, Rustemli et al. [19] emphasize that PV technology is a very attractive renewable energy option for clean energy production. Rustemli and Dincer [20] support that solar energy has a significant existence on a large part of the world, and solar energy comes at the top of the list because of its abundance and more equal distribution in nature than other types of renewable energy. It is expected to become the technology leading to the lowest cost of solar electricity according to the developed technology, and solar energy is an important energy source because of its clean and renewable nature [21,22]. Abu-Khader et al. [23] note that the solar energy is becoming more and more a viable source of energy for many industrial and housing appliances. Kannan et al. [24] note that non-fossil energy sources are explored, and power generation from PV systems plays a prominent role. Sherwani et al. [25] outline that electricity generation from solar energy bring about environmental benefits such as reducing greenhouse gas and pollution.

As being different process from the other renewable energy sources, solar radiation can be converted into heat or directly electrical energy. It can be absorbed by solar collectors to get heat water or air and it can be also converted directly into electrical energy by PV process. This process does not increase carbon dioxide production and does not harm the environment. Thus, PV power systems have received considerable attention among the clean energy resources as a solution for the environmental problems in the worldwide scale [26]. Many studies show that PV technologies appear quite attractive for electricity generation because of its noiseless, no carbon dioxide emission in terms of operating, scale flexibility, rather simple operation and maintenance [27–30].

Among the European Countries, Turkey has a remarkable solar energy potential. And, region of Manavgat in Antalya is one of the sites where the solar potential is considerably high for both in winter and summer season. Also, seasonal ambient temperature in the region rises to affect PV efficiency in direction of decrease. Therefore, in this study, first, a review and an analysis of solar energy data with seasonal variation in region of Manavgat are examined by simulations. Obtained results from PV Geographical Information System (PVGIS) for both two-axis tracking system and fixed-angle PV systems are discussed and compared with each other. In addition to that, temperature effects on PV systems performance are also reviewed and analyzed by simulation studies briefly because of daily high temperature of the region. PV system installed in the region, as a case study, is introduced with some details and harvested data from this plant is presented and made a discussion on the seasonal results in winter. Afterwards, some actual harvested data from thin film and monocrystalline type PV panels are evaluated from point of efficiency and temperature effects on them. In conclusion, an evaluation of the study is done, and discussion for selected region in terms of both solar energy potential and using different PV panels for installation is presented. As consequence, two-axis sun tracking system is suggested to improve system performance and increase the yields of the system to be installed in the region of Manavgat. Besides, no distinctive difference between thin film and monocrystalline panel in terms of the yields for this region is concluded because of high ambient temperature, except for cost of panel, stand-alone efficiency and its place to be covered on the installation area.

2. Overview of the sun tracking systems

The conversion efficiency of a PV cell, or solar cell, is the percentage of the solar energy shining on a PV device that is converted into electrical energy. Improving this conversion efficiency is a key goal of research and helps make PV technologies cost-competitive with more traditional sources of energy. Several factors affect a cell's conversion efficiency value, including its reflectance efficiency, thermodynamic efficiency, charge carrier separation efficiency and conduction efficiency values [31]. By convention, solar cell efficiencies are measured under standard test conditions (STC) unless stated otherwise. STC specifies a temperature of 25 °C and an irradiance of 1000 W/m^2 with an air mass 1.5 (AM1.5) spectrums. These conditions correspond to a clear day with sunlight incident upon a sun-facing 37°-tilted surface with the sun at an angle of 41.81° above the horizon [32,33]. The efficiency of the solar cells used in a photovoltaic system, in combination with latitude and climate, determines the annual energy output of the system. For example, a solar panel with 20% efficiency and an area of 1-m² will produce 200 W of

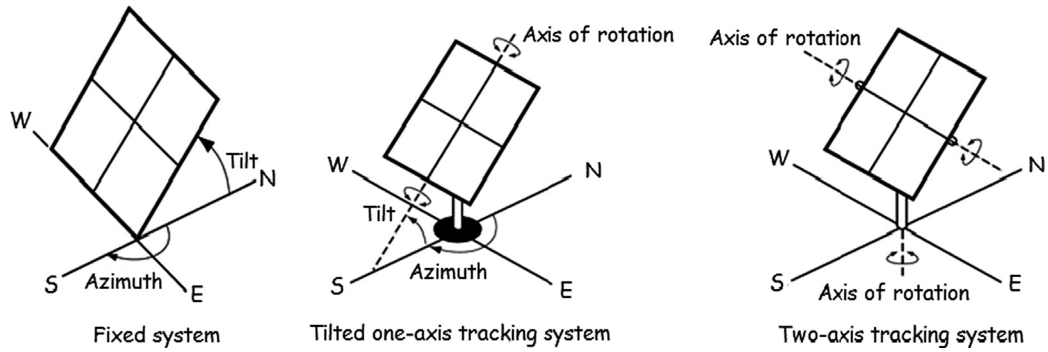


Fig. 1. Schematic representation of the fixed tilted and one- and two-axis sun tracking systems [38].

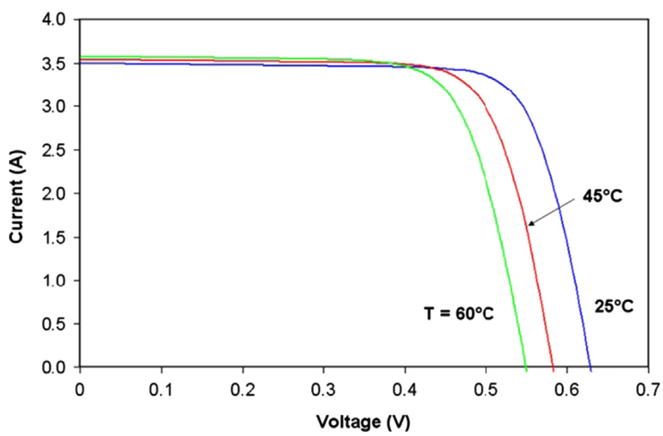


Fig. 2. The effect of temperature on the IV characteristics of a solar cell [35].

power at STC, but it can produce more when the sun is high in the sky and will produce less in cloudy conditions and when the sun is low in the sky [34].

However, there are some applications in practice and literature such as sun tracking, cooling systems for PV panels, etc. to increase capacity of electricity generation of PV panels. One of the most useful methods among those systems is the sun tracking. Tracker systems follow the sun during the day as a certain degree of accuracy since the sun is continuously moving. As the sun′s position changes hourly, orientation of the solar power devices should be adjusted to generate the maximum output power [23]. Although increasing the initial investment cost, sun tracking systems accelerate recovery of the costs because of generating maximum power during day by tracking the sun. And, fewer panels may also be used for harvesting the same power.

Rustemli et al. [19] outline that use of sun tracking system increases productivity by around 29% compared to the fixed-angle system. Mousazadeh et al. [36] express that increasing of power consumption in tracking system is about 2–3% of being produced energy. In addition, Abu-Khader et al. [23] studied on multi-axes (Nourth–South, East–West, vertical) electromechanical sun-tracking systems. They found that there was an overall increase of about 30–45% in output power for the North–South axes tracking system compared to the fixed PV system. Abdallah and Nijmeh [37] experimentally studied on sun tracking systems. They investigated the effect of using two axes tracking on output efficiency of PV power system, and they also found that two axes tracking surface showed a better performance with an increase in the collected energy of up to 41.34% compared to the fixed surface. Kivrak et al. [22] outlined that the difference between performance of a fixed tilt PV panel and a two-axis tracked PV panel was compared for months of May and June, and it was found that the energy generation increased nearly 64% by tracking system in summer season with respect to the fixed PV system. Schematic representation of the fixed tilted and one- and two-axis sun tracking systems is shown in Fig. 1.

3. Effects of temperature on monocrystalline and thin film PV panels

Increasing of operating temperature in PV cells affects the efficiency of PV cells negatively. The main cause of the temperature rising in the cell is the weather conditions at which PV panels are located. In other words, ambient temperature is the main factor from point of the efficiency decrease. On the other hand, while a PV cell performs the electricity energy conversion, its operating temperature also increases due to the structure of the cell. As the temperature rising in the cell, the cell current is slightly increased, but the voltage considerably decreases rapidly, as shown in Fig. 2. The result, at the same time, shows a lower power yield. Therefore, efficiency of PV energy conversion is much lower in some regions which have high average ambient temperature in comparison with the other places.

Many studies in literature have mentioned negative effects of temperature on PV panels. Many researchers present some studies on how to improve efficiency of PV cells to recover the negative effects of increasing operation temperature [28,48,49–62]. Behavior of the solar cells varies under temperature changes. The change in temperature affects the power output from the cells. The voltage is highly dependent on the temperature and an increase in temperature causes to decrease its voltage. Thus, operating temperature plays a central role on the PV conversion process. Efficiency of PV cells is strongly affected by their operating temperature, noted by Ye et al. [56,57].

It is well-known that most of the solar radiation absorbed by a PV cell is not converted into electricity but contributes to increase its temperature, thus reducing the electrical efficiency, outlined by Mattei et al. [58]. In general, crystalline silicon PV cells efficiency will be reduced about 0.5% for every °C increase in temperature [59]. Therefore, temperature of PV cells is one of the most important parameters for assessing the long term performance, noted by Malik et al. [60].

Most commercial solar cells are made from a highly purified silicon crystal, similar to the material used in the production of computer processors. The high cost and complex production process of these silicon solar cells has generated interest in developing alternative photovoltaic technologies. The listed power of a solar cell is the power measured under ideal laboratory conditions, which prescribe a temperature of 25 °C (77 °F). However, on a typical hot summer day, it is not uncommon for a solar cell to reach a temperature of 70 °C (158 °F). In terms of the materials, the temperature coefficients for C–Si cell and *p*-Si cell change between −0.3%/°C and −0.4%/°C. This indicates that conversion efficiency of

the cell is strongly affected by the temperature coefficient [49]. Typical temperature coefficients are given in Fig. 3. Also, typically for every 1 °C increase of cell temperature, amount of ~0.45% drop in module efficiency occurs for crystalline silicon modules. However, the efficiency loss for thin-film modules is only approximately half of crystalline silicon technology [56]. Another study, Strevel et al. [61] note that crystalline silicon solar modules typically have temperature coefficient of −0.45 to −0.5% per degree Celsius. Thin film panels retain a higher voltage output under direct high temperature and they can generate over 20 V at 75 °C surface temperature. The thin film type of PV system is more cost effective for tropical regions. So, thin film panels always give 30% more energy per year in hot climates, than crystalline panels [62,63].

Many different photovoltaic materials are deposited with various deposition methods on a variety of substrates. Thin-film solar cells are usually categorized according to the photovoltaic material used, such as amorphous silicon (a-Si), thin-film silicon (TF-Si), cadmium telluride (CdTe), copper indium gallium selenide (CIS or CIGS), dye-sensitized solar cell (DSC) and other organic solar cells.

There are many studies on monocrystalline and thin film technologies [40–46]. Munoz-Garcia et al. [40] report that thin film photovoltaic technology provides some advantages such as stability, high efficiency for low material costs. However, thin film technology materials are limited resources (indium and gallium) compared to the abundance of Si [41]. Kessler and Rudmann [42] note that the future for efficient, lightweight, flexible and cost-effective thin-film modules looks very promising. Dhere [43] outlines that thin film modules do not require such wafers and hence they used to have a substantial cost advantage estimated at 50% over crystalline solar cell technologies. So, Dhere [43] adds that since 2006, the production of thin film solar cell in the U.S. has surpassed that of crystalline solar cell.

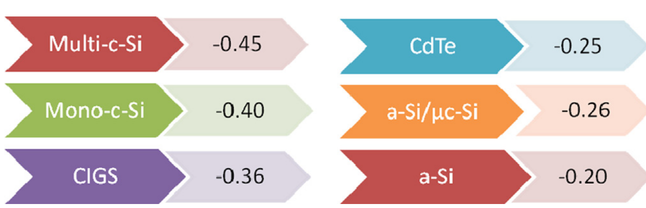


Fig. 3. Typical approximate temperature coefficients ($P_{MPP}(\%-K)$ for different technologies.

4. Investigation of solar energy potential in the region

4.1. Site and data description

Set of data are provided for Manavgat region in Antalya, which is located in the South part of Turkey (Location: 36.790 North, 31.463 East), as shown in Fig. 4. Also, the city of Antalya has one of the highest solar energy potentials in Turkey. Fig. 5 shows the solar energy potential map for Antalya. Total solar radiation average is approximately 1780 kW h/m^2 Manavgat region has some advantages of weather conditions for solar energy potential in Antalya because yearly average temperature is about 18 °C approximately [47]. Therefore, this region was selected to install a PV power plant by using different panels from point of investigation temperature effects on the system performance in winter season and evaluate the regional solar energy potential, as the first project in the region.

4.2. Investigation of solar energy potential in the region

By considering mentioned futures of the PV panel types, this part of the study presents an online example for the sun tracking system to bring up its efficiency in terms of more electricity generation. Besides, the data to be obtained by like this example can give useful information for any selected area in European Countries, without any additional cost. This sample models were designed by PV Geographical Information System (PVGIS) [47]. PVGIS incorporates a solar radiation database and gives climatologically data of European as well as the other countries. PVGIS makes the simulation possible to calculate long-term average values and daily profiles of the irradiation on PV modules. PVGIS estimations have been widely used by developers to compare energy generation between fixed and tracking installations, as well. In addition, it can be used to calculate the theoretical and achievable energy generation by different PV configurations. All of the simulations by PVGIS are introduced for the region of Manavgat in Antalya. The values given in Tables 1 and 2 and Fig. 6 are obtained for this area.

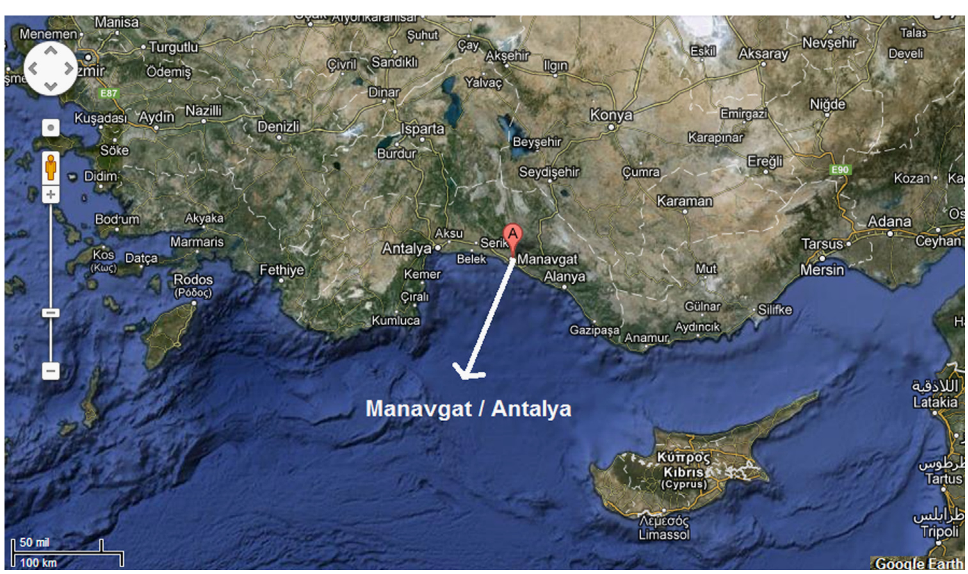


Fig. 4. Location of the selected region of Manavgat by Google Earth.

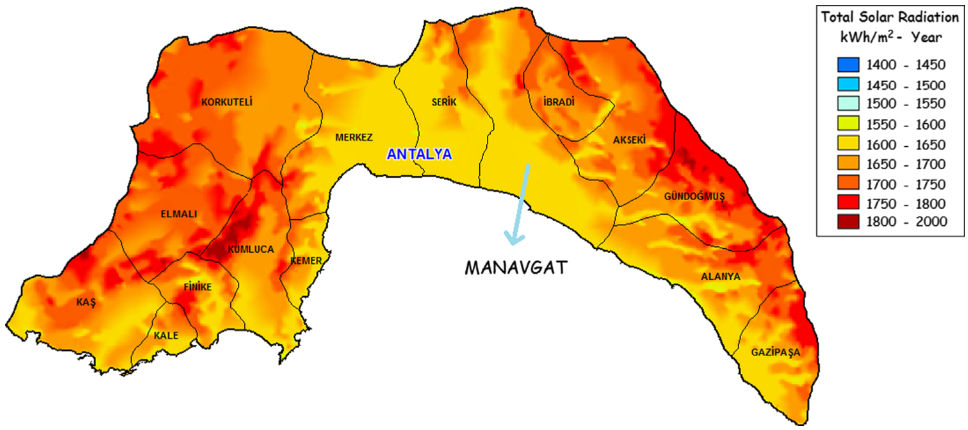


Fig. 5. Solar energy potential in Antalya and region of Manavgat.

Table 1
PVGIS values of thin film system from fixed-angle and two-axis tracking installation.

Month	Fixed system: inclination = 32°, orientation = −1°				Month	Two-axis tracking system			
	Ed	Em	Hd	Hm		Ed	Em	Hd	Hm
Jan	5.38	167	4.05	126	Jan	6.98	216	5.41	168
Feb	6.36	178	4.88	137	Feb	8.28	232	6.49	182
Mar	7.78	241	6.11	189	Mar	10.40	323	8.27	256
Apr	8.13	244	6.43	193	Apr	11.10	334	8.84	265
May	8.78	272	7.11	220	May	13.00	404	10.60	327
Jun	9.28	278	7.60	228	Jun	14.50	436	11.80	355
Jul	9.39	291	7.73	240	Jul	14.30	442	11.70	362
Aug	9.30	288	7.67	238	Aug	13.30	413	10.90	338
Sep	8.91	267	7.28	218	Sep	12.20	366	9.94	298
Oct	7.57	235	6.05	188	Oct	10.10	313	8.15	253
Nov	6.24	187	4.83	145	Nov	8.24	247	6.54	196
Dec	5.37	167	4.05	126	Dec	6.95	215	5.39	167
Year Av.	7.71	235	6.15	187	Year Av.	10.80	329	8.68	264
Totally		2820		2250	Totally		3940		3170

Table 2
PVGIS values of monocrystalline system for fixed-angle and two-axis tracking installation.

Month	Fixed system: inclination = 32°, orientation = −1°				Month	Two-axis tracking system			
	Ed	Em	Hd	Hm		Ed	Em	Hd	Hm
Jan	5.76	178	4.05	126	Jan	7.41	230	5.41	168
Feb	6.80	190	4.88	137	Feb	8.79	246	6.49	182
Mar	8.28	257	6.11	189	Mar	11.00	341	8.27	256
Apr	8.62	259	6.43	193	Apr	11.80	353	8.84	265
May	9.29	288	7.11	220	May	13.70	425	10.60	327
Jun	9.80	294	7.60	228	Jun	15.20	456	11.80	355
Jul	9.90	307	7.73	240	Jul	14.90	462	11.70	362
Aug	9.79	304	7.67	238	Aug	13.90	431	10.90	338
Sep	9.39	282	7.28	218	Sep	12.80	383	9.94	298
Oct	8.01	248	6.05	188	Oct	10.60	328	8.15	253
Nov	6.64	199	4.83	145	Nov	8.70	261	6.54	196
Dec	5.75	178	4.05	126	Dec	7.37	229	5.39	167
Year	8.17	249	6.15	187	Year	11.40	345	8.68	264
Totally		2980		2250	Totally		4140		3170

First, geographical location is determined, and then fixed and two axis tracking systems for thin film PV panels are chosen to simulate with the selected parameters below:

Location: 36°47′24″ North, 31°27′46″ East, Manavgat
Elevation: 18 m
Nominal power : 1.8 kW CIS (thin film)
Estimated losses: 14.1% (due to temperature and low irradiance using local ambient temperature)
Estimated losses: 2.6% (due to angular reflectance effects)
Other losses: 14.0% (cables, inverter etc.)
Combined losses: 28.1%
Ed: Average daily electricity production from the given system (kW h)
Em: Average monthly electricity production from the given system (kW h)
Hd: Average daily sum of global irradiation per square meter received by the modules of the system (kW h/m²)
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kW h/m²).

Where, the sample system is designed by taking the characteristic values detailed in Table 2 into consideration for 125 W_p-thin film PV panel, and results are shown in Table 1 and Fig. 6a. Geographic system, photovoltaic panels and system information are examined by this software. Electrical energy generation capacity of the system is indicated and depicted by diagrams, month by month.

Second, obtained results are shown in Fig. 6b and Table 2 if the sample system is designed by taking the characteristic values detailed in Table 1 into consideration for 240 W_p-monocrystalline PV panel. Electrical energy generation capacity of the system is indicated and depicted by table and diagrams for the whole year, month by month.

Location: 36°47′24″ North, 31°27′46″ East, Manavgat
Elevation: 18 m
Nominal power: 1.9 kW (crystalline silicon)
Estimated losses: 17% (due to temperature and low irradiance using local ambient temperature)
Estimated losses: 2.6% (due to angular reflectance effects)
Other losses: 14.0% (cables, inverter etc.)
Combined losses: 30.4%

In Figs. 7 and 8, incident global and in-plane irradiation for the studied region, Manavgat, are given to show high potential of the region. Also, in case of using sun tracking system, inclination angle variation of the panels through a year is shown in Fig. 8. It is clearly seen that if fixed-angle system is used to harvest solar energy, optimum angle of the installed panel is not appropriate for achieving maximum efficiency, for example in winter season.

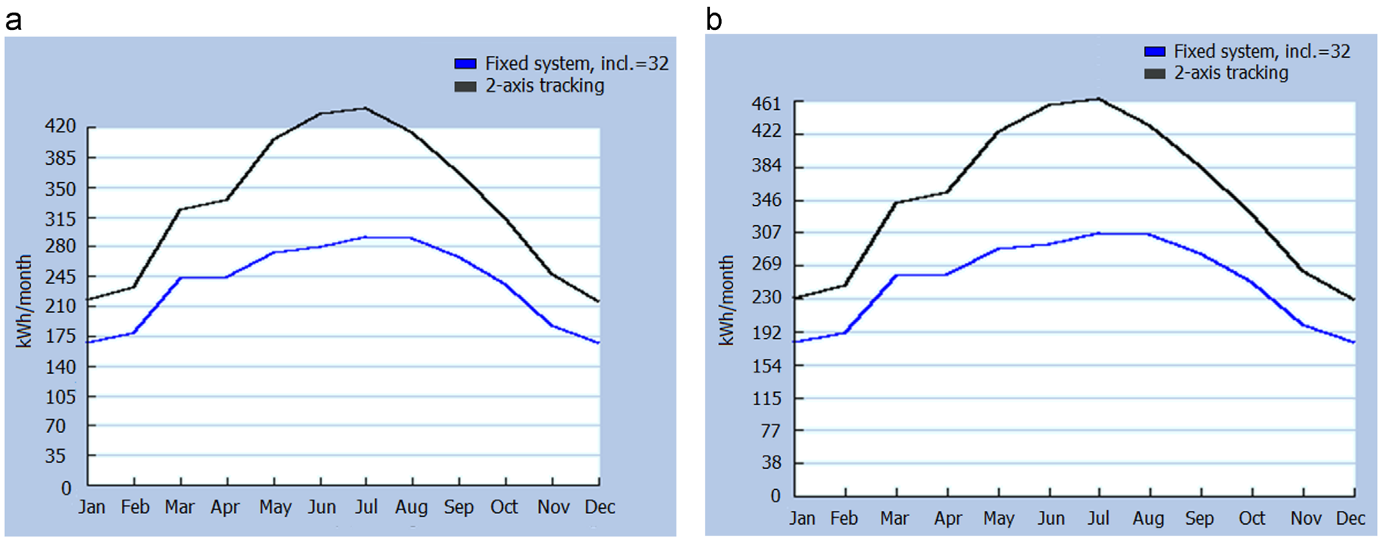


Fig. 6. Monthly energy output from two-axis and fixed-angle installation. (a) by 1.8 kW-thin film types, (b) by 1.9 kW-crystalline silicon types PV panels.

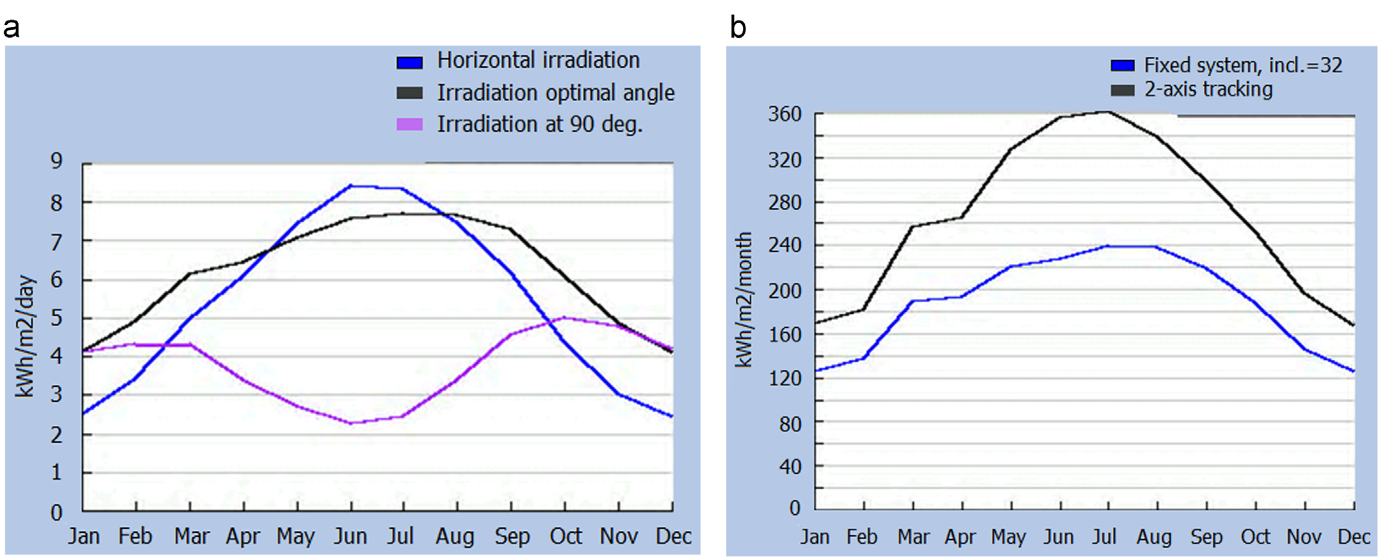


Fig. 7. (a) Incident global irradiation and (b) monthly in-plane irradiation for the chosen location.

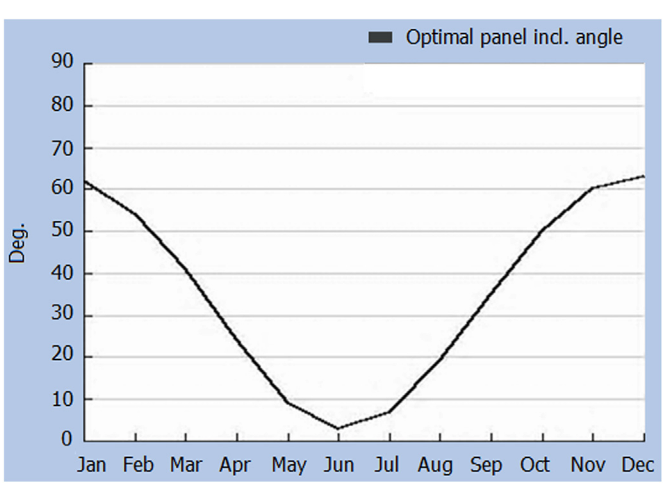


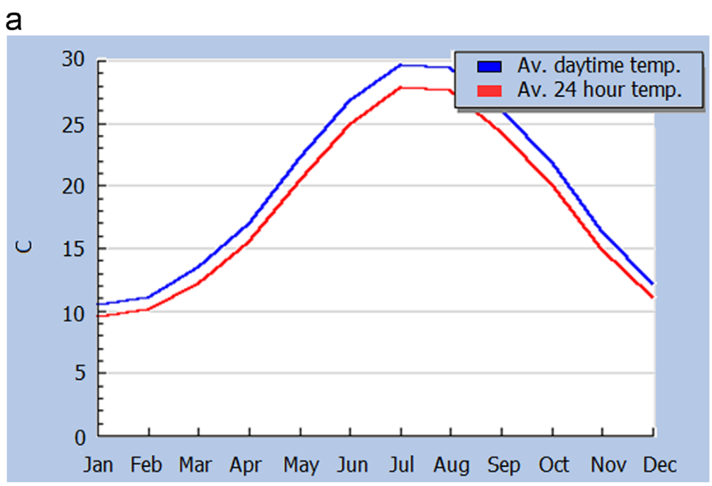
Fig. 8. Optimal panel inclination to be adjusted in tracking system through the year.

4.3. Temperature variation in the region

In Manavgat, the average ambient temperature changes in a wide range. For example, in winter and summer season the ambient temperature changes nearly between 12 °C and 40 °C, respectively. Therefore, effects of changes in temperature on efficiency of PV cell will be more important. During the whole year average values of ambient temperature and outline of horizon with sun path diagram are shown in Fig. 9.

5. A case study for Manavgat in winter season

In this study, generated electricity measurements taken from the plant installed on the roof in region of Manavgat are analyzed and the results are compared with and the simulations. Also, outputs of two different panel types used in the PV power system are evaluated in terms of electricity generation and their yields. The harvested data can be used for developing a solar energy



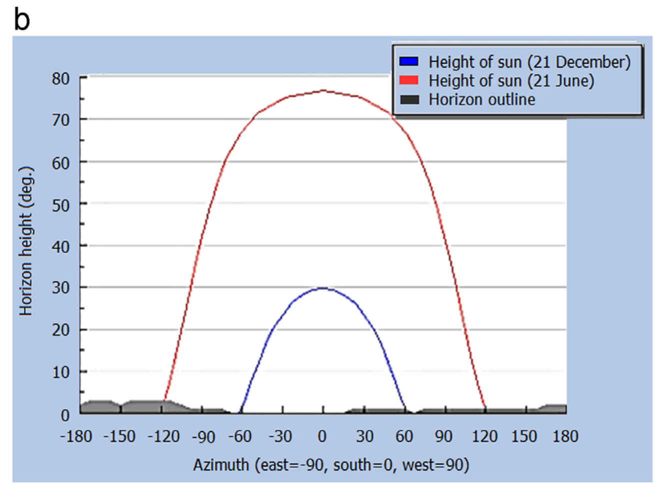


Fig. 9. (a) Average ambient temperature for the whole year, (b) outline of horizon with sun path for winter and summer solstice in region of Manavgat [47].

Fig. 10. A view of the installed PV system on the roof.

Table 3
Electrical characteristic of 240 W_p monocrystalline PV panel.

Nominal power	$P_{max}-(W)$	240
Efficiency of PV panel	$\eta-(\%)$	14.75
Voltage at maximum power	$V_{mp}-(V)$	29.4
Current at maximum power	$I_{mp}-(A)$	8.16
Open circuit voltage	$V_{oc}-(V)$	37.2
Short circuit current	$I_{sc-}(A)$	8.71

Table 4
Electrical characteristic of 125 W_p thin film PV panel.

Nominal power	$P_{max}-(W)$	125
Efficiency of PV panel	$\eta-(\%)$	11.7
Voltage at maximum power	$V_{mp}-(V)$	44
Current at maximum power	$I_{mp}-(A)$	2.84
Open circuit voltage	$V_{oc}-(V)$	59.3
Short circuit current	$I_{sc-}(A)$	3.22

model which describes the mathematical relations between the harvested data and the meteorological variables such as ambient temperature, humidity, and sunshine ratio [39].

5.1. Details of the PV power system installed

Manavgat PV power system has two different PV panel types. These are monocrystalline and thin film type. In the system, monocrystalline PV panel used in the plant has power of 240 W_p. The number of total installed monocrystalline PV panel is eight (*totally* 1920 W_p) and thin film PV panel used in the plant has power of 125 W_p and the number of this type panel is 14 (*totally* 1720 W_p), as shown in Fig. 10. Also, Tables 3 and 4 show characteristics of these PV panels.

5.2. Analysis of the harvested data

This section also provides analysis of the generated electricity from the installed PV power system on the roof in Manavgat. Figs. 11 and 12 show harvested solar energy in Manavgat from December 2012 to January 2013. In December, the harvested energy of kW h per square meter mainly changes between 4 and 5 kW h/daily. But, the energy yield increases up to be just around 5 and 6 kW h/daily in January 2013. Power system consisted of monocrystalline and thin film PV panels generated energy of 120.61 kW h and 105.18 kW h in December 2012, respectively. Also, monocrystalline and thin film PV panel systems generated energy of 143.57 *kW h* and 125.72 *kW h* in January 2013, respectively.

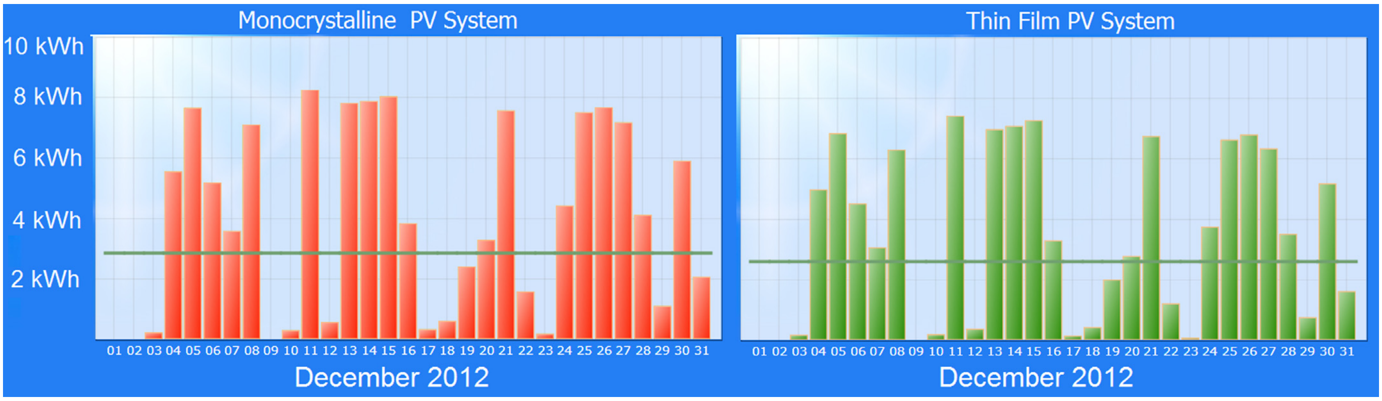


Fig. 11. The electrical energy harvested in the plant, in December 2012.

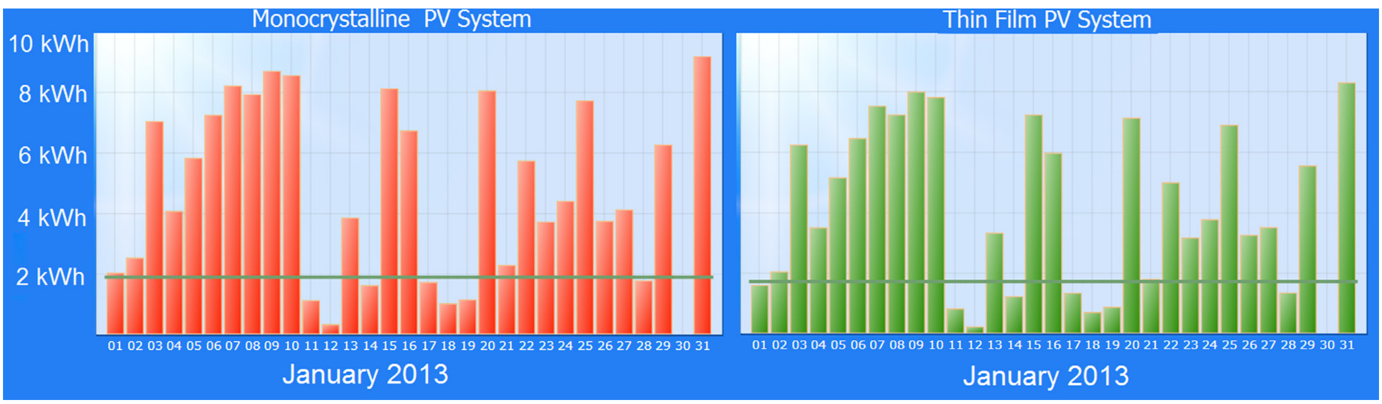


Fig. 12. The electrical energy harvested in the plant, in January 2013.

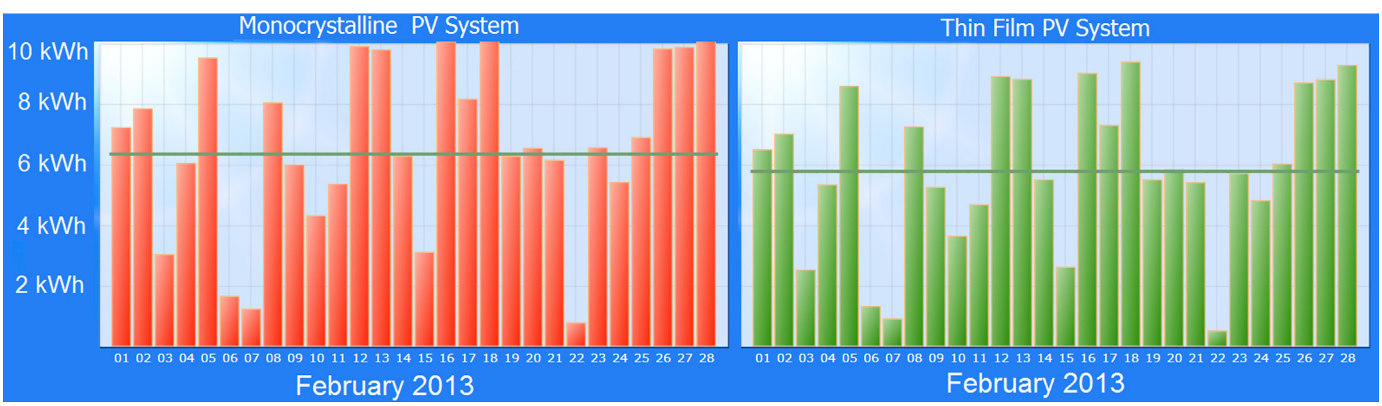


Fig. 13. The electrical energy harvested in the plant, in February 2013.

Figs. 13 and 14 show harvested solar energy in Manavgat from February 2013 to March 2013. In February, the measurements arrive around 6 and 7 kW h/daily, because of long exposure time of the sunlight. Generated electricity increases compared to the January. Since exposure to the sunlight during day in March is greater than in February's, generated electrical energy increases to be around 7 and 8 kW h/daily for the current day. Monocrystalline and thin film PV panel system generated energy of 185.74 *kW* h and 164.35 *kW* h in February 2013 and also monocrystalline and thin film PV panel system generated energy of 246.37 *kW* h and 219.24 *kW* h in March 2013, respectively, as shown in Table 5.

6. Conclusion

Turkey has a large potential of renewable energy sources, and the city of Antalya has also one of the highest solar energy potentials in Turkey. Especially, solar energy potential is very abundant among the other developed countries. In this case study, it is emphasized that the measurements and actual production data collected in Manavgat region in winter season support this high potential. Also, this study is the first solar power project in the region. Besides, yearly ambient temperature is high enough to influence panel efficiency. Therefore, different panel types are used to evaluate the degree of this influence. On the other hand,

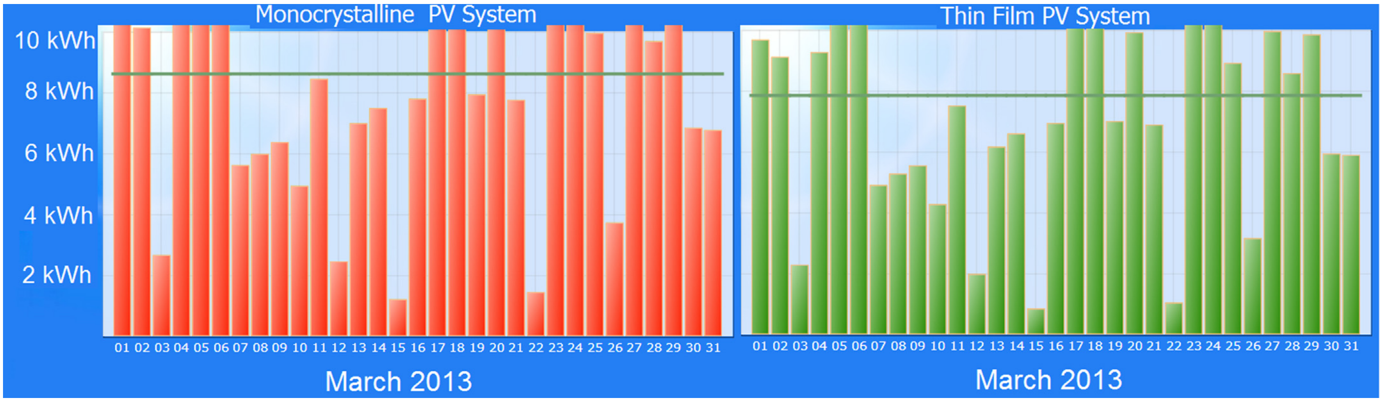


Fig. 14. The electrical energy harvested in the plant, in March 2013.

Table 5
Harvested average data from the plant and proportional values.

Panel types	December-2012	January-2013	February-2013	March-2013
Monocrystalline (actual harvested)	120.61 kW h	143.57 kW h	185.74 kW h	246.37 kW h
Thin films (actual harvested)	105.18 kW h	125.72 kW h	164.35 kW h	219.24 kW h
Thin films (proportional to the same power of Monocrystalline's)	117.41 kW h	140.33 kW h	183.46 kW h	244.73 kW h
Daily-avg. from the plant	4–5 kW h/m^2	5–6 kW h/m^2	6–7 kW h/m^2	7–8 kW h/m^2

it is shown by simulation studies that total energy for the year based on average monthly electricity production is about 1690 kW h by the fixed-angle system and 2390 kW h by two-axis tracking system, per kilowatt installation for both systems. According to these results, for only 4-months in winter season, actual harvested solar energy is over the expectations. In addition to that, these data give a proof that two-axis tracking PV system generates more electricity than fixed-angle system for this region, as well. So, it can be expressed that sun tracking system can compensate for the cost of initial investment rapidly. Also, it is possible to use fever PV panel for generating the same expected power.

From another aspect, it can be concluded that apart from cost of the PV panel and its covered place to be installed, there is no prominent difference between thin film and crystalline type PV panel system from point of solar energy harvesting in Manavgat because of its convenient weather conditions for the both panel types. On the other hand, as taking cost of the panels into consideration, owing to this project it can be evaluated that thin-film PV panels can be used in the region more favorable because of the less effects of high ambient temperature on thin film PV panel's efficiency in comparison with monocrystalline type's.

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